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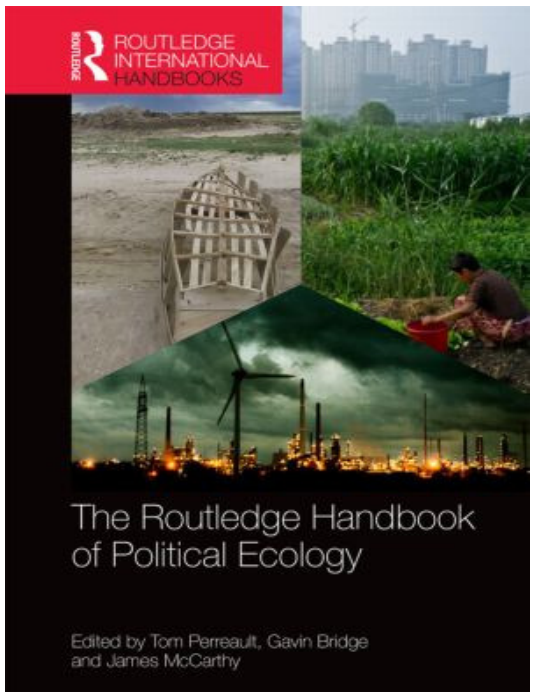
Contact Prof. Gavin Bridge, Department of Geography, Durham University
g.j.bridge@durham.ac.uk



Industrialization and environmental change

Stefania Barca and Gavin Bridge

Industrialization is one of the great markers for periodizing socio-ecological relations. It describes the second major ecological transition in the history of humankind, the first being the shift from hunting and gathering to agriculture that occurred in the Neolithic (Cipolla 1973, Steinberg 1986, Wrigley 1988). Industrialization is credited with driving the emergence of the 'Anthropocene', a term which likens the past 250 years to a geological era characterized by the ability of humans to alter geo-ecological processes on a global scale, and exemplified by the anthropogenic forcing of atmospheric CO_2 from 280 to 400 ppm (Steffen et al. 2011). Such readings of industrialization, however, highlight material transformations at the world-scale, and overlook equally significant processes of geographical and social differentiation. Since its inception in the second half of the 18th century in the English countryside, industrialization has been a continuous process of socio-ecological transformation and differentiation that has simultaneously pulverized and re-constituted social and geographical relations across all spatial scales. By accelerating the appropriation of raw materials and generation of wastes (Muradian et al. 2012), commodifying labour and land, and remaking human bodies through the consumption of industrial goods (Guthman and Mansfield, this volume) and exposure to radioactive, metal and persistent organic pollutants (Boudia and Jas 2014, Higgins 2010, Harremoes et al. 2002), industrialization may be considered a form of 'slow violence' (Nixon 2011) that both reproduces and transforms inequalities in economic and political power. Given industrialization's wrenching socio-ecological transformations – and the complex narratives, norms and subjectivities that variously sustain and query the social relations of which it is productive - it is somewhat surprising that political ecology has paid industry only limited attention. For the most part, political ecology has approached industrialization obliquely, and one needs to look to the field's fluid borderlands with environmental history, environmental sociology and ecological economics to find a more sustained engagement.

This chapter considers political ecology's limited engagement with industrialization. We suggest that although the field's foundational interest in livelihoods and modes of production has skewed strongly agricultural, some of political ecology's conceptual resources may be reworked to consider industry and industrialization. We share with recent writing in political ecology a wariness of the Anthropocene on account of its "fetish of industrialization" (Moore 2014: 13) and attention to temporal differentiation rather than the production of socio-spatial difference. However, we make the case for a political ecology focused on the distinctiveness of industrialization's socio-ecological relations: the appropriation of ecological surplus in the form of inanimate energy, rapid growth in the technical composition of capital, and the geographical expansion and temporal acceleration of social metabolism that has sustained the growth of labour productivity over time. This framework, we suggest, can illuminate the political

ecological significance of industrial labour regimes in wringing value from biophysical systems, and the environmental inequalities, ecological risks, and distribution conflicts consequent to an industrial mode of production (Martinez-Alier 2002). We conclude that a focus on industry and industrialization need not detract from understanding longer-term dynamics of the capitalist production of nature, and highlight the opportunities of a more thoroughly industrial political ecology.

The Power and the Machine: industrial capitalism

One of the core strands around which political ecology has evolved as a field is an interest in the social relations, technical practices and ecological conditions of conservation, agriculture and extractive industries. This interest has, in the main, led researchers to focus on struggles among different social groups for access to - or control of - the capacity of specific parcels of land to produce environmental goods and services. For the most part, this interest in understanding how forces, relations and conditions of production combine to appropriate surplus in ways that sustain economic and political power has not extended to the manufacturing sector (although see Walker et al. 1979 for a nascent political ecology's interest in the chemical industry). Yet processes of mechanization, the concentration of capital, and the socio-spatial distribution of economic surplus and pollution are no less significant in manufacturing than they are in primary production. Indeed, the amassing of capital and the fundamentally entropic character of this sector suggest it is arguably the primary driver of social and spatial differentiation across a range of scales (Bunker 1985, Hornborg 2006). This section outlines the significance of industry as a mode of production, focusing on the conjoined effects of mechanization, inanimate power and the elevation of labor productivity as a 'metric of wealth' (Moore 2014: 20).

At its core, the term "industrialization" indicates a shift from manual to mechanized forms of production in all or most phases of the labor process. A consequence is a growing mass of machinery relative to labor time, what in Marxist terms is referred to as a rise in the technical composition of capital. However, this quite specific meaning has become indistinguishable from broader social meanings of the term. Since its early uses in the English language between the 1790s and 1830s, the word 'industrialism' has been associated with the idea of a new social order, a revolution "based on organized mechanical production" (Williams 1983: 166-167). Here, two of the most pregnant meanings of the word power – in its social sense of command over people and in the physical sense of ability to carry out work – came to converge, leading to a new mode of production: industrial capitalism. Such convergence of meaning was the result of an underlying shift from manual to mechanized production, which first emerged in the industrial mills of England where a formerly autonomous and physically dispersed workforce came to be concentrated and disciplined in the factory system.

Contrary to what is often assumed, however, the core of the industrialization process is not the machine per se, but the energy source which moves it: what distinguishes industrial production from other manufacturing systems is that 'inanimate' power, not humans or animals, moves the machine (Wrigley 1988). Even if the use of inanimate energy pre-existed in a variety of activities (the most important being the grinding mill), a series of technical improvements allowed such automation to spread over the entire labor process rather than being isolated to a few phases, thus starting the era of mechanized mass production. In short, industrialization is synonymous with the use of non-living energy in the production of commodities.

Mechanization, however, does not imply that machines do the entire job that was previously done by human labor. Rather, the latter becomes the living component of a mechanized and automated process, made up of inanimate power sources, complex mechanical clusters, and organizational schemes aimed at regulating the input-output flow (energy and materials, labor, commercial products and waste). The industrial workplace can thus be seen as a peculiar kind of ecological system (McEvoy 1995), made up of biological processes (workers' bodies), thermodynamic properties (power sources and machines) and social regulation (engineering, labor relations, law). The history of the industrial workplace, however, shows that such particular ecologies have a tendency to become highly politicized and produce outcomes such as social unrest, reform or revolution (Barca 2014, Santiago 2006).

Industrialization was first set in motion by a peculiar form of inanimate energy: waterpower. It was water and not coal that moved the wheels of the textile mills of Yorkshire, Lancashire and Derbyshire in England in the late 18th century – and that first showed how much more money could be made out of mechanized production, due to its unprecedented ability to intensify the labor process (Malm 2014). Industrial capitalism was born and raised in the river valleys of Europe and North America, where the fundamental elements of a new system of ecological relations were first put into place. Those elements can be summarized as: (1) the appropriation of water as a form of 'natural capital' for the extraction of mechanical energy (waterpower) and the production of exchange value; (2) the mechanization of labor; and (3) the production of a new landscape – the early industrial riverscape – with its peculiar narrative and representation (Barca 2010).

With the later shift from waterpower to steam, however, industrial capitalism appropriated a far larger ecological surplus and set in motion a widespread experimentation with a third, crucial meaning of the word 'power': the thermodynamic property of concentrated energy which, while employed to move machines, is then dispersed and lost forever. Identified by French engineer Sadi Carnot in 1833 during his studies of the steam engine, the second law of thermodynamics – also known as the entropy law – is understood as a (meta)physical limit on the industrial economy (Daly 1991, Georgescu-Roegen 1976). Profoundly reconfiguring the organization of living and non-living matter in the biosphere, and the

chemical composition of the atmosphere, industrialization has acted as a powerful accelerator of entropy for the last two hundred years (McNeill 2000).

The political ecological significance of industrial assemblages for harnessing inanimate energy (like steam power) relates not only to the step change in the amount of energy available to societies. Such an expansion in energy availability also enabled a qualitative shift in the organizational logic of economic life, by allowing human labor to be substituted on a massive scale. In particular, industrialization changed the relationship to land in a significant way, from "a direct relationship of surplus appropriation" to "a condition for rising labor productivity within commodity production" (Moore 2014: 20). The significance of industrialization, then, lies in the coupling of machines and inanimate power, and their combined revolutionary impacts on labor productivity (Bridge and Bradshaw 2013).

By tapping inanimate sources of power, the industrial organization of work gains a seemingly 'automatic' character, in the sense that its pace and intensity do not depend anymore on those of living beings. This is an illusion, of course, a mystification of the productive forces and social relations of the industrialization process. Nevertheless, the technical ability to harness non-human forces to the machines, in ways which allowed the mechanization of the labor process from start to end, had vast and multiple consequences. The physical limits of labor could be overcome by simply replacing the workforce operating machines in prolonged or even continuous shifts (as in blast furnaces); inanimate sources of power do not eat and thus do not compete with humans for appropriation of biomass, so they constitute a net gain in the total amount of energy available in society. In short, the ecological limitations of the "advanced organic economy" (Wrigley 1988) could be overcome. People now tended the machines as operators, not as movers. Coupled with the institution of private property and the historical process of capital accumulation, such energy shifts created a fundamental break with pre-industrial modes of production, for it set in motion a mechanism that was virtually unstoppable. As long as there was water running through the wheels, or coal burning in the steam engines, production could continue apace. All that was needed was a disciplined and subdued workforce to make sure that power did not go to waste, and a market demand large enough to absorb the sheer volume of goods coming out of the factory system. This is why the industrial revolution would be hardly understandable outside the historical context of the agrarian enclosures and dispossessions – which created a proletarian workforce – and of the geo-political context of European colonialism – which created a market for the industrial products of England and north-western Europe (Foster 1999; Hornborg 2001; Barca 2011).

Given this historical context, we suggest that a political ecology of industrialization focused on power and the machine may be read in two different ways. First, understood narrowly as an account of the environmental impacts of mechanization, a political ecology of industrialization highlights the accelerated throughput of energy and materials (including finished goods and waste) between a society and its bio-

physical environment. It focuses not on machines per se, but on the intensification of control over labor and revolutionary effects on labor productivity that lead to growing socio-ecological inequalities. So significant is the acceleration in the rate of industrial metabolism (Fischer-Kowalski and Haberl 2007) that it measurably alters the chemistry of the atmosphere; so extensive is the harnessing of biophysical forces that it becomes possible to speak of "second nature" (Smith 1984: 4); and so profound are the inequalities generated via ecologically unequal exchange, resource exhaustion and widespread environmental degradation that the world becomes differentiated into industrial centers and their extractive peripheries (Bunker 1985). This first approach approximates quite well political ecology's relatively limited engagement with industrialization, which has focused largely on ecological distribution conflicts and the environmental risks associated with industrialization (as we illustrate below).

Second, when understood more broadly as an account of the economic rationales, social relations and subjectivities consequent to industrialization, a political ecology of industry extends beyond environmental impacts to include forms of economic and political life to which industrialization gives rise. This expanded approach enables one, for example, to interpret crises of over-accumulation and industrial strategies to restore profitability in political ecological terms (Desfor and Vesalon 2008); or, similarly, to understand struggles over the distribution of gains from improved labour productivity as a (Fordist) political ecological settlement extending beyond the workplace to permeate consumption and social reproduction (Huber 2009). This second approach remains a road less travelled within political ecology, although work by Huber (2013; see also this volume) and Mitchell (2011) are important exceptions precisely because they seek to capture the systemic and ecological character of socio-political relations consequent to oil-fuelled industrialization. For Mitchell, for example, the enormous productive potential of oil as an inanimate energy source – specifically, the prospect of growth without limit - was an important condition of possibility for the emergence of the modern notion of economy. While for Huber, a political ecology of the 'golden years' of post-war industrialization in the United States acknowledges the role of oil in "the alienated – seemingly autonomous – power of capital over living labour" (2013: xiv), and in giving shape to forms of 'entrepreneurial life' and political identity readily conformable to neoliberalism through suburbanization and automobility. We return to these broader readings of the political ecology of industrialization in the conclusion. The next two sections address the social metabolism of industrialization and production of environmental risk.

The Country and City: social metabolism and the treadmill of production

Industrial activity requires high-intensity inputs of energy, materials, and human work. Structured by a productivist logic of continually expanding output, this anthropogenic flux of materials, energy and wastes simultaneously creates extractive frontiers and new markets for mass consumption. In this way the 'social metabolism' of industrialization drives processes of socio-spatial differentiation at all geographical

scales, and underpins distinctive forms of ecological consciousness. For the most part, political ecology has approached these trans-local provisioning systems from the upstream end: research originates in fields, forests, mines, waters and other sites of raw material production and considers how the social relations of resource access and use are structured by wider processes. Urban political ecology, of course, takes a different tack and highlights the city as a site of commodity consumption and political power structuring and shaping socio-spatial flows of materials (Heynen et al. 2006). However, industrial processes – the dynamics of transforming and capturing value via the physical transformation and (re)assembly of raw materials into manufactured products – are often occluded in these accounts. In the case of agro-food, for example, political ecology accounts typically start with either agricultural practices or (to a lesser extent) the politics of consumption and food access, with the result that agricultural processing and food manufacturing appear primarily as contextual detail rather than an explanatory focus. A notable exception is Walker's (2004) account of 150 years of agribusiness in California, which highlights the central role of this sector in driving processes of innovation that, in turn, transformed both spaces of production and consumption. Similarly political ecologies of oil are weighted strongly towards processes and spaces of extraction: rarely has political ecology placed refining, plastics and petrochemicals at the center of its account, notwithstanding the tremendous scientific, technological and legal efforts of this sector towards the re-assembly and social proliferation of hydrocarbon products. Robbins (2007, see also Robbins and Sharp 2008) is noteworthy for its interest in the chemical production complex and the role of declining margins in driving the suburban lawn care economy. Huber's (2013: 61) explicit attention to petroleum refining and refinery workers as a "central metabolic site" in the socio-ecological relations of 20th century capitalism is indicative of how political ecology might pay more attention to the dynamics of industrial production and to what effect.

Through growing labour productivity and product specialization, industrialization throws an unprecedented volume of commodities into circulation: such an enormous growth in manufacturing typically drives down unit exchange values, thereby opening up markets for mass consumption, while at the same time causing recurrent over-production crises. The logic of maximizing production is pervasive: it increases profits, state revenues (through taxation), and national, corporate and personal prestige and power. This implicit social critique of industrial capitalism is captured by the concept of "the treadmill of production," first theorized in the late 1970s based on observations of the Fordist system (Schnaiberg 1980). The treadmill argument describes a political-economic system based on manufacturing and driven by a fundamental belief that social welfare and wellbeing are advanced through economic growth: the constant expansion of production and consumption become the key instrument of social policy, around which there is a convergence of interests between capital, labor and the state. Mechanisation to improve labour productivity expanded demand for energy and resources, while the fixed capital sunk in machines required high rates of throughput to be sustained (Gould et al. 2004). Since "sustained ecosystem withdrawals and additions" are required to expand production and consumption "the support of private

capital, labor, and the state for economic growth (imply) conscious or unconscious support for ecological disruption and environmental degradation" (Gould et al 1996: 7). In the Fordist era this system was organized primarily at the national scale, although over time it has become increasingly transnational as a consequence of processes of economic globalization that, in turn, have accelerated the treadmill.

The political ecological significance of industrialization rests not only on the expansion of production and consumption. It also concerns the increasing differentiation between country and city – and between core and periphery - propelled by industrialization, a process captured in the notion of 'metabolic rift' (Foster 1999; Foster et al. 2010). In his discussion of "Large-scale Industry and Agriculture" in Volume I of *Capital*, Marx noted how industrial capitalism collected population in large urban centers, thereby disturbing the return of nutrients derived from human, animal and organic waste to the soil: at the same time, capitalist agriculture undermined both the soil and the ability of workers to reproduce themselves by an unprecedented intensification of production. As a consequence, Marx and Engels were "insistent about the need to transcend this form of alienation from nature upon which capitalism rested….the argument involved the abolition of the antagonistic relation between town and country through the integration of agriculture and industry, the dispersal of population, and what Marx referred to as "the restoration" of the metabolic relation between human beings and the earth" (Foster 2000: 182-83). The "geographical promise" (Moore 2011: 9) of metabolic rift as a critical perspective has captured the attention of those seeking to understand how spatial differentiation arises out of the political ecological inner relations of capitalism. For the most part this work has been taken up in environmental sociology and has focused on the restructuring of biogeochemical cycles consequent to industrialisation: Clark and York (2005), for example, examine industrialisation's disruption of the global carbon cycle and the flooding of atmospheric carbon sinks; while Clark and Foster (2009) develop a more richly geographical account of metabolic rift and unequal exchange in their work on the 19th century trade in guano and nitrates from South America to restore European soil fertility (see also Hornborg, this volume). Notwithstanding this important work, the "eco-geographical logic" to which the concept of metabolic rift alludes – and which arguably constitutes "one of critical political ecology's most powerful ideas" - has yet to be fully explored by political ecology (Moore 2011: 39).

The eco-geographical differentiation of space represented by 'country and city' re-works socio-ecological relations at both material and symbolic levels, and is thus productive of new forms of environmental consciousness and politics. Indeed, the differentiation of country and city has had significant cultural and ideological repercussions. A number of scholars have pointed out how historically it gave rise to an elitist vision of the environment as a place for leisure and recreation, and for the conservation of an imagined wilderness devoid of human interaction and work (Cronon 1996, Merchant 1980). Originating as an expression of rural nostalgia on the part of English elites during the first industrial revolution (Guha 2000, Marx 1964, Smith 1986), such purifying urges towards 'wild nature' have frequently translated into

authoritarian and racist conservation policies (Steinberg 2002; Kosek 2004). These largely elite versions of a white, Anglo-Saxon ecological consciousness do not automatically apply to other social classes and cultures, however: research on the ecological consciousness of the industrial working class, and of non-white communities, reveals quite different attitudes towards nature conservation and environmental pollution. Important discriminating elements are occupation and income: post-material environmentalist concerns (around biodiversity conservation or climate change, for example) have a much higher price for the working-class than for the middle or upper classes, as the former tend to be more directly dependent on dirty industrial jobs, and thus to be subjected to so-called 'job blackmail' (Obach 2004, Barca 2014).

The fertile notion of an 'environmentalism of the poor' expresses a distinctive environmental consciousness that arises from the socio-spatially unequal distribution of ecological goods and bads (Martinez-Alier 2002). Social movements calling for global environmental justice, including proposals for 'post-extractivism' (Gudynas 2013) and 'Buen Vivir' (Radcliffe 2012; Gudynas 2011) as alternative models of regional development, seek explicitly to politicize both the treadmill and eco-geographical character of industrial social metabolism. In this respect, they are part of a long-line of social movements that have challenged the separation between country and city. These include, for example, anarchist and utopian organizations practicing the principle of "back to the land" as a response not only to urban alienation, pollution and loss of economic autonomy (as in European and North-American neo-ruralism), but also to the proletarianization of the rural workforce and the environmental and public health threats posed by industrial monocultures (as in the agro-ecology movement of Latin America, and elsewhere in the global South). Food security, food justice, and self-dependency are common goals for a number of rural and urban-farming movements worldwide, which have acquired growing importance and self-awareness in the last decade (Gottlieb 2002). The contemporary 'de-growth' movement –which shares its heterodoxy with political ecology and ecological economics, and to which European political ecology has been a significant contributor - is a strikingly normative project that seeks to re-politicize the socio-ecological relations of industrial growth in order to slow the treadmill of production and achieve an equitable and "prosperous way down" (Kallis 2013). A self-consciously alternative proposition to sustainable development, the de-growth movement articulates a political ecological consciousness that 'affirms dissidence' with mainstream models of economy (Demaria et al. 2013: 192; D'Alisa et al. 2014).

Ecological modernization and the political ecologies of environmental risk

Industrialization and modernity are closely associated within social theory: the former is credited with the emancipation of pre-modern societies from the tyranny of nature to enable their full material and cultural development, and also with the growing domination of nature (including humans) expressed in the concerns of the Frankfurt school. For example, an increase in energy consumption per capita is a commonly accepted indicator of 'modern economic growth' as it testifies to the ability of sustaining

production growth at a rate higher than the growth of population (Foster 1999; Peet et al 2011). Historical increases in energy consumption per capita have, in practice, been inextricably linked to the harnessing of inanimate energy sources (mostly fossil, but also hydro and nuclear power). Mainstream economic discourse celebrates such trends in labour productivity and consumer welfare as a triumph of western modernity over pre-industrial resource supply crises, which brought recurrent famines as a consequence of societies' inability to sustain production. Ecological modernization theory replicates this progressive role for industrialization, but focuses on technological and managerial improvements to resource productivity and eco-efficiency that enable 'leaner' forms of industrial production: i.e. the production of more output with lower energy and material inputs (Mol 1995). Lauded as a process of 'de-materialisation' observable at the level of individual products, this process ignores both the problem of aggregate resource consumption (which outstrips resource efficiency gains at the level of individual products) and specific environmental risks associated with the social metabolism of a putatively 'post-industrial' society.

Political ecology has a long record of critically challenging conventional accounts of modernity. Although relatively little work focuses on either the manufacturing sector or processes of industrialization, political ecology has developed an extensive critique of industrial-forms of resource management and the field is characterized by a pervasive skepticism towards accounts that assign scarcity to nature (rather than society) and which present undifferentiated accounts of economic or environmental change. Political ecology has been slow to apply these critical lenses to the sites and spaces of manufacturing, but shows a growing interest in understanding the environmental and social consequences of ecological modernization through work on sectors like electronics manufacturing (Forsyth 2004; Little 2012); e-waste disposal (Pickren 2014a, 2014b); and renewable energy (Mulvaney 2013). Forsyth (2004) illustrates the potential of a 'brownfield' political ecology – as distinct from a greenfield focus on farms, forests and other forms of rural transformation – that examines the politics of environmental and social risk associated with rapid industrialization. In his work on Thailand, Forsyth highlights lead and solvent poisoning among electronics workers and the health effects arising from the combustion of lignite in power plants closely associated with the country's drive for industrial growth. His analysis centers on the politically-generative capacity of industrial pollution which, via the epistemology of class-based environmental movements in Thailand, successfully created an environmental consciousness around 'dirty development' as a way to challenge the state. He also points out how the cases of lead and lignite have become "hegemonic environmental imaginaries in their own right" within the Thai environmental movement, subsequently structuring understandings of risk in restrictive ways. Ulrich Beck's concept of "risk society" has been taken up by a number of researchers in political ecology to highlight a paradigmatic organizational shift arising from the increase in technological hazards associated with industrial production: a shift from the distribution of wealth to the allocation of risk (Beck 1992, Hannigan 2006). In a general sense the circulation of industrial toxins in the environment and their concentration in living organisms may be

considered to be 'democratic' phenomena, as they affect society at large (Beck 1987). However, more careful observations reveal how pollutants tend to concentrate in specific spaces and thus affect the particular human groups that inhabit them (Faber 2008). In this way unequal exposure to the effects of industrialization gives rise to significant spatial and social differentiation. Even when toxic substances or carcinogens circulate more widely, as in the case of contaminated food or water, some human populations are more vulnerable to them than others because they do not have access to means of self-protection and "inverted quarantine" – e.g. eating organic food – which are put in place by more affluent sectors of the population (Szasz 2007; Renfrew 2013). The political ecologies of industrial contamination have, therefore, frequently been interpreted through the lens of environmental justice (Little 2012; Pellow and Brulle 2005; Holifield, this volume).

Although there is now a rich body of work on environmental (in)justice associated with industrialization, there are surprisingly few political ecologies of the industrial workplace in what historians of occupational health and safety refer to as the "dangerous trades" (Hamilton 1985). In modern industrial societies the tyranny of nature has been replaced with an "industrial hazard regime" characterized by an unprecedented intensification of work hazards, leading to a contradiction between work and health - production and reproduction - common to both capitalist and centrally planned economies (Sellers and Melling 2012; Merchant 1980). Such a contradiction starts at the workplace: a crucial but often forgotten aspect of industrialization is the way it dramatically changes the work environment and the life conditions of the working classes, deeply altering disease patterns at the global level. This fact has been clearly perceived since the beginning of industrialization: the Marxian tradition of thought saw industrialization as a contradictory process bringing about an unprecedented advance in the forces of production, but with enormous social and environmental costs. In *The Condition of the Working Class in England* (1845), Engels exposed the enormous social cost of industrialization paid by the English working class through occupational hazards and the impairment of urban living conditions. Their contemporary, William Morris, was alarmed by urban pollution and the toxic environment in which industrial workers were compelled to work and live. "The proletariat thus became a universal class," writes J.B. Foster, "exposed to 'universal pollution' and universal suffering, a class threatened with the total loss of humanity, and one that could emancipate itself only through the total emancipation of humanity" (Foster 2000: 119). Scholars in public health and historians of medicine have long identified the fundamental epidemiological shift which characterizes industrialized societies, that from a prevalence of infectious to degenerative diseases (Sellers 1998). Such an epidemiological shift is a major consequence of industrialization, carrying broad social, ecological, and bio-political implications which, notwithstanding excellent work in environmental history and histories of public health (e.g. Nash 2007; Santiago 2006), deserves greater attention on the part of political ecologists. A political ecology of industrial hazards and environmental risk would start from the work environment, looking first at the effects of industrial work on human-nature (e.g. workers' bodies); it would then follow the flows of carcinogens and mutagenic particles from the shop-floor (or the farm-

field) to the larger environment, in their meeting with the local landscape and living organisms; and finally their circulation through the atmosphere, the water cycle and the food chain. At the same time, however, the circulation of industrial hazards must be seen as a socio-technical process founded upon geo-political and economic inequalities, which is constantly renegotiated through the production and circulation of knowledge, and the possibilities for social subjects to become aware of and counteract those hazards.

Conclusion

As an empirical object of inquiry, political ecology has given industrial activity comparatively limited attention. Industrialization appears in political ecology primarily as a process that imperfectly penetrates the social relations of agriculture, as a motor of resource mobilization and social metabolism, and/or a source of new forms of technological and environmental risk. We have outlined in this chapter ways to build on these significant yet still limited engagements to develop a more thoroughly industrial political ecology. Centering an account on the political ecological relations that sustain labour productivity – and highlighting mechanization and the appropriation of ecological surplus in the form of inanimate energy, technological intensification, and the expansion and acceleration of social metabolism – can illuminate how industrial labour regimes extract value through the transformation of biophysical systems, and the environmental risks and distribution conflicts consequent to an industrial mode of production. Conceptual resources developed in other heterodox fields of inquiry – such as ecological economics, and sections of environmental history and environmental sociology – can be useful in this task: the concept of 'metabolic rift', for example, may be turned towards understanding how industrialization drives processes of spatial differentiation, and its implications for both socio-ecological outcomes and forms of political-ecological consciousness.

There is a tendency in environmentalist accounts of industry to fetishize machines and resources: what Moore (2014: 12) describes as a bourgeois distraction that "it all began with coal". We have argued, however, for a political ecology that acknowledges the distinctive character of industrial activity and which critically engages the environmental and social consequences of mechanization: here the focus is not on machines and inanimate energy in and of themselves, but on their revolutionary implications for labor productivity and socio-spatial differentiation. Importantly, however, a political ecology of industrialization should go further than an account of its environmental and social impacts, to consider the subjectivities, rationalities and habits of mind to which industrial activity gives rise.

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